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Urban Battlespace Control: A New Concept for Battle Command

Topics: C2 Analysis, C2 Concepts and Organizations, C2 Modeling and Simulation

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# **URBAN BATTLESPACE CONTROL: A NEW CONCEPT FOR BATTLE COMMAND**

## **ABSTRACT**

An accurate picture of areas controlled by opposing forces would help commanders gauge battle progress. The Army Research Laboratory has a well-developed prototype to visualize degree of control in open battlespace regions. The system computes power projection over time and space, based on probabilities of hit and kill, position, weapon effectiveness, and damage, and updates its display as new information is received. The urban battle presents difficulties in transforming the mathematics and portraying control. This paper discusses our efforts to extend the ownership paradigm and software for urban operations. Urban ownership may be essentially categorical, rather than numerical. It is more subjective, reflecting dismounted presence, imperfect pictures of the enemy, and novel weapon utilization. To what extent is a building “owned” if it can be destroyed? Is a floor owned if weapons can be fired from below? Infrastructure influences (communications, water, power, transportation) must be carefully modeled, and line-of-sight issues are complex. Demographic, human-intelligence data in multi-sided operations involving civilians must be considered. Multi-dimensional regions must be displayed intuitively. This is challenging research, but with a high-payoff: predicting urban battle areas of concern in a timely way provides a significant new type of command and control decision aid.

## **Introduction**

Commanders and their staffs are required to evaluate disparate pieces of information in order to provide a course of action (COA) for mission completion. As a COA is enacted, the mission must be monitored to assess success and to decide if plans or asset allocations must be altered. The Battlespace Decision Support Team (BDST) of the U.S. Army Research Laboratory (ARL) is currently developing the Battlespace Terrain Ownership (BTO) system as a new decision aid for command and control. This proof-of-principle system has demonstrated the visual portrayal of battlespace control in open terrain. However, urban and complex terrains provide new challenges. Our current efforts are focused on enhancing the BTO control algorithm and system to incorporate additional factors unique to the urban environment.

## **Background**

BDST has been exploring for several years the applicability of combat simulation to networks, information, and integration. Specifically, our endeavors have centered on COA evaluation and metrics for the planning/re-planning process of modern combat. Our objectives are: develop and evaluate COA decision methodologies for the Future Force mobile commander; establish connections between constructive simulations and actual battle; extend the mathematics of combat modeling for COA analysis; and move fundamental research products into Army facilities for usability evaluations. The scope includes the development of a consistent set of tools that assist staffs in various aspects of battlespace decision support (e.g., wargaming, planning, analysis, execution monitoring) and techniques that aid the warfighter in rapid situation analysis and decision making. Our work involves research toward decision aid methodologies to develop

and evaluate COAs for military operations on urban terrain and to develop architectures using data for both battle planning/gaming and execution/monitoring. The intent is to apply experimental mathematical techniques and statistical analyses to improving the understanding of simulated battle dynamics, leading ultimately to the shaping of the actual urban battlespace. This work is intended to lead to an integrated system to dynamically link automated plan generation and analysis with execution monitoring.

In 2004 we completed work on a prototype algorithm and program to give visual representation of opposing forces' control of the battlefield.<sup>1</sup> The algorithm generates expected control, or "ownership", by each combatant based on a projection of power onto areas of the battlefield. We also developed software to visually display a color-coded representation of areas owned and the degree of that ownership. Seeing dynamic areas of control should aid the commander in predicting battle areas of concern in a timely way. We have linked the prototype into the streaming data from a combat simulation to demonstrate real-time updates.

Our current focus is extending a dynamic decision aid prototype into the urban operations domain with a more user-friendly graphical user interface. We see no serious problems in extending the algorithm to more complicated open-terrain situations. However, urban operations present conceptual difficulties in transforming the mathematics of ownership, and visualization difficulties in portraying meaningful results. This work is challenging research, but we believe it has high payoff despite the risks. Work planned includes: improvements to the display; collaboration with other urban operations (UO) researchers; and investigation of new analytical techniques.

## **BTO Overview**

The ARL has developed the BTO system to reduce critical battlespace information into a graphical display. During development, we used a laboratory test environment to produce combat data utilized by the BTO algorithm. A combat simulation (One Semi-Automated Forces (OneSAF) Testbed Baseline (OTB) v2.0) was modified to provide battle entity status data<sup>2</sup> and information on fire events<sup>3</sup> (direct and indirect) to feed the BTO algorithm. Hooks can be included in the BTO system to replace the simulated data with live data feeds from intelligence sources and sensors in the future.

BTO currently has three components: the combat simulation, which provides entity information; the translation program, which monitors and formats the simulated data; and the algorithm, which incorporates and displays the information. For the first component, we use OTB. A typical scenario lay down is depicted in Figure 1. Throughout the combat simulation scenario execution, data is collected. At a user-specified interval, information is obtained for all battlespace entities. This information comprises an entity's unique identification, location, ammunition and fuel supplies, and status (undamaged or firepower, mobility, firepower/mobility or catastrophic kill). If the simulation user does not specify a data collection interval, the system will provide updated data every sixty seconds.

The simulation also provides information on all fire events. If it is a direct fire event, the simulation provides firer and target identification, the location of the firer and target, the type of

ammunition, the angle of attack, the round dispersion, and the result of the event. For an indirect fire event, information is provided as to the location of all impacted entities, location of the detonation, round used, and entity outcomes.

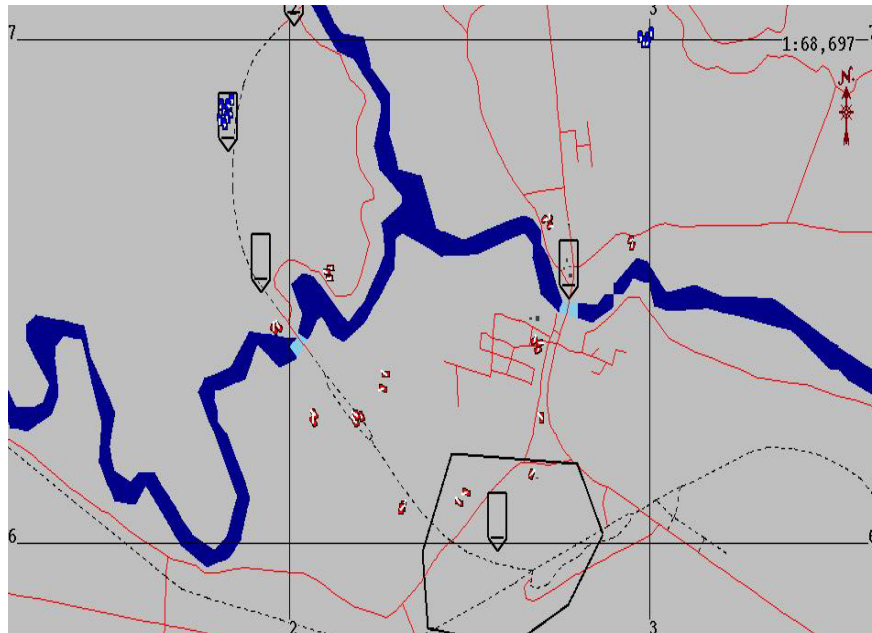


Figure 1. OTB scenario lay down.

The second component of the BTO system is the translation software. The software, written in Java, constantly monitors the data produced by the simulation on entities and fire events. All fire event data is passed onto the BTO algorithm. Entity information is provided only if the information has changed since the last report. The software also formats all data for the algorithm software.

The third component is the software that provides the control algorithm and graphical display. The software dynamically computes terrain control based on combat power projection as a function of position, influence exerted by asset distribution, weapon system effectiveness, probabilities of hit and kill, and combat damage. Using this information BTO creates a graphical display of the battlespace featuring zones of combat power to yield an understanding of terrain control.

Figure 2 depicts a two dimensional display of the scenario with control colorations. In this display the areas of control by the enemy forces are shaded as the reds, with the darker colors being areas of greater control. The friendly forces are shades of blue with the darkest blue being the area of greatest control.

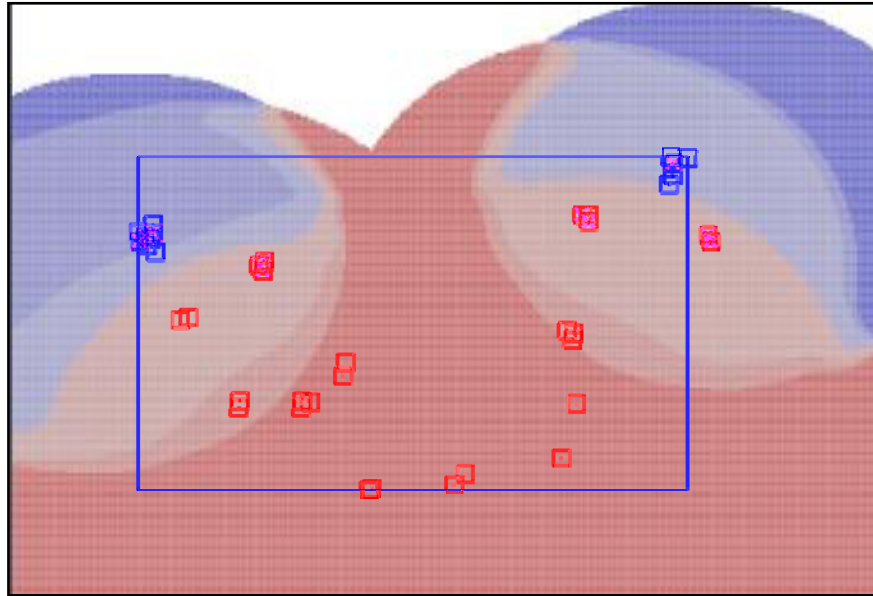


Figure 2. 2D control display.

We are also able to provide the control colors on top of 3D terrain, as shown in Figure 3. The user can navigate through the 3D terrain, which improves the applicability to urban situation awareness. We currently do not have the battle entities on the 3D terrain, but current work involves registering the entities on the terrain and displaying their movements and status.

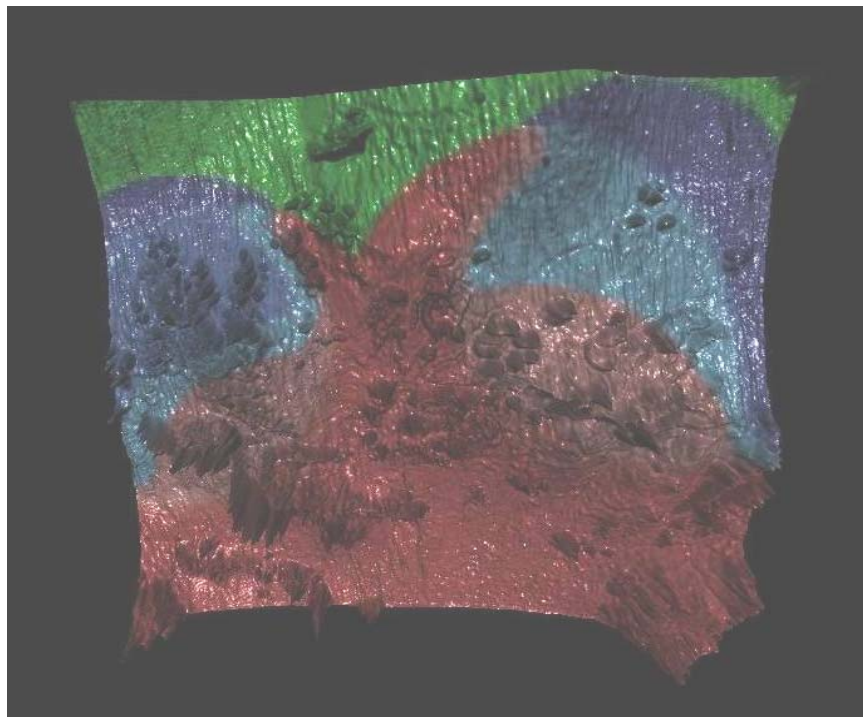


Figure 3. 3D terrain with control colorations.

The BTO algorithm software was developed in the C programming language. Due to the use of Java and C the system is relatively portable. All components of BTO reside on a single Linux system. BTO can run on a small laptop. Future work includes porting BTO to a tablet or personal digital assistant.

## **Urban Conflict**

The Army recognizes that the urban environment is complex and multi-dimensional.<sup>4</sup> The urban battlespace involves aspects of terrain; for instance, gross district patterns with attached finer street patterns. It involves societal characteristics such as population centers. It involves interdependent infrastructures. We will briefly mention some fundamentals of urban operations, to provide a framework for extending BTO toward UO applicability. A particular conceptual focus for this development is urban intelligence preparation of the battlefield (IPB), where we note that the dynamics are generally replete with asymmetric attributes. In this vein, the threat will in general operate in a decentralized and dispersed manner so as to attempt to neutralize U.S. technological advantage, deny access, control the nature and tempo of the conflict, and produce unacceptable casualties. Their tactics will involve attempting to win the information war, use the civilian population, tamper with key facilities, and attack support areas and isolated personnel. Urban combat tends to produce food and water shortages, pollution and disease, and unstable power structures. All these must be factored in, at least qualitatively, to analyze urban ownership in a meaningful sense.

The urban infrastructure can be considered in terms of both the physical structures of the environment (both natural and artificial) and the people that inhabit or utilize these structures. We are interested, for the purposes of ownership, in politico-economic aspects of transportation, commerce, distribution, communications, and administration. Information, energy, and human services are of particular importance in influencing urban interactions and ownership.

All military operations are based on fundamentals; aspects of traditional operations are of course incorporated in UO. Conventional aspects of combat include force type and strength, vulnerabilities and casualties, equipment, time, avoiding collateral damage, and so on. Humanitarian aspects include preserving the infrastructure and services. Combined aspects include such matters as controlling the essential, separating combatants from noncombatants, performing information operations, and properly transitioning control. However, in UO almost all of these are necessarily changed by the complex environment, and the latter two categories of fundamentals are particularly challenging to factor into ownership computations.

Somewhat simplistically, UOs can be classed as offensive, defensive, and stability and support. However, in general, offensive operations involve qualities of surprise, boldness, and force concentration; defensive operations involve preparation, security, and adaptability. Stability and support operations are particularly concerned with interactions with the civilian population and organizations not necessarily directly connected with the conflict.

The military decision-making factors of distance, time, and force density tend to be “compressed” in UO. Of particular interest to us in extending the existing BTO is the notion of

compressing combat power. Urban terrain increases the effects of some weapon systems, resulting in an increase in power. For instance, a concealed and protected sniper may influence operations to a much greater degree in urban as opposed to open terrain. Ground combat power is also compressed by complex terrain that prevents engagements at extended range. Our standoff advantage is diminished; short-range threats increase significantly. Moreover, vehicles may be positioned within a few meters of each other to enable massed fire and mutual support, increasing the chances of several systems being targeted by one threat. Also, target acquisition (TA) is generally degraded by dense urban clutter, resulting in decreased combat power, even if the density of TA systems is increased in an attempt to compensate.

The population of civilians in an urban environment affects operations in many ways. The urban operator must consider various aspects of the society that have traditionally not been factored into combat planning (other than, perhaps, by Special Forces). Politics and history, religion, culture and ethnicity, personalities of leaders, the demographics and health of the populace – all these factors and more influence the tasks of the urban operator. All these contribute to development of what we might call (with varying shades of meaning) interaction, influence, control, or ownership.

Of course, exactly how these are to be factored into UO analysis is problematic. Many attempts have been made, for example in the form of summarization handbooks. Guidelines such as avoidance of projecting ones' own thinking or values onto the person being assessed are offered as "tools" for helping anticipate civilian actions. However, for the purposes of assessing ownership these are necessary but not sufficient. Our BTO extension project is attempting to develop algorithms for integrating and displaying urban information immediately available to the commander.

Participants in any UO must consider a variety of attributes of any group that has, or may have, an effect on the operation. Certain structural aspects are relatively straightforward to assess: size, location, leadership, and organization. Other aspects are more difficult to quantify, much less determine the implications of: interests, capabilities, and intents. However, given that such group attributes can at least be reasonably approximated, the urban operator can develop appropriate COAs. These COAs may not be thought of as traditional combat; for instance, procedures may have to be generated for the purpose of enabling the military force and an indigenous civilian agency to jointly accomplish a goal, or to help stabilize basically neutral parties. We see in the current southwest Asia situations that the Soldier may be involved in such para-military operations as establishment of areas restricted to civilians and enforcement of ration control.

Whether such operations can be used to define ownership may be open to debate. However, it is clear that these measures do provide influence and control and are subject to quasi-objective assessment. We therefore intend to incorporate such actions into the BTO algorithm analogously to, say, weapon firings, or perhaps better, minefields. Of course, a problem is that the effects of such operations are not as straightforward as those that result from utilization of munitions. In many cases, the determination of non-immediate effects of munitions is not straightforward either. But these can be derived, if only on an empirical or historical basis; and so can the effects of other types of influence or control.



Various products or tools, some commercially available, may be brought to bear on the problems of UO IPB. These include overhead imagery, infrastructure blueprints, and hydrographic surveys. Of course, not all information is physical in nature: demographic surveys or even psychological profiling may be factored in if available. All these sources can be combined to form multi-dimensional data representations or geospatially-registered map overlays.

We anticipate that the BTO calculations must have more dimensions and dependencies than in the existing system due to the effects matrices from urban or effects based operations. That is, effects will depend not only on the firer and target physics as now, but on the history of the conflict, for example, and the intent of the enemy. It seems clear that it is impossible to distill into a single number the influence resulting from the confluence of various factors in a region of the battlespace. For instance, what does it mean numerically that the population has poor health, yet access to high-powered weapons? Perhaps variants of rule-based systems may be best in developing what we might call categories of influence.

## **Interview Results**

BDST has been able to demonstrate a graphical display of terrain control. The control is dynamically determined and the display is updated as new information is received. In an effort to keep the Soldier in the forefront of BTO development, BDST traveled to the Battle Command Battle Lab – Leavenworth (BCBL-L) in September 2005. In a one-day visit, BDST team members interviewed nine subject matter experts (SMEs). The interviews were held with groups of two to three SMEs for a period of one to two hours each. The SMEs included active and retired military. Each group was shown a ten-minute briefing on BTO and then the software was run. The groups could watch the battle play out in OTB and see the control display change as events occurred. The SMEs were then interviewed on how to improve BTO for the Soldier and how to adapt BTO for urban engagements. Suggested improvements have been prioritized and will be added to BTO in the future. The urban considerations are discussed in the following paragraphs.

Some of the SMEs had recently returned from Operation Iraqi Freedom. They provided numerous personal accounts of urban conflicts. One point raised by numerous participants was that urban control may be more subjective than objective. Personal involvement is much more critical. It was emphasized that things such as a reliable interpreter can make or break a mission. The SMEs agreed that it is critical to identify three or four top factors that provide a decisive edge.

It was also emphasized that socio-economic data is more critical in an urban environment than in open terrain. Civilian populations can greatly impact an urban conflict, sometimes just by sheer numbers. The SMEs asked that not only control be shown in the BTO display, but that it have the ability to provide additional information such as areas of civilian populations or densities.

The SMEs stated that at times just presence will afford control. They related stories that even though Iraqi civilians were more heavily armed, the coalition forces had control of the area merely by being seen. Firepower can not be the only determinant for control in an urban setting.

The SMEs also suggested that in an urban environment, dismounted infantry (DI) may have a greater combat effectiveness than, possibly a tank platoon. Their added mobility and capability to enter smaller areas increases the DI's lethality.

The SMEs recommended that additional factors needed to be modeled. These included infrastructure elements (e.g., electricity, water, sewers, communication networks and gas lines), man-made obstructions (e.g., roadblocks and rubble), contamination areas, and force degradation. It was mentioned that with regards to force degradation that an infantry unit may degrade at a faster rate than an armor unit due to the psychological aspects of face-to-face combat. The SMEs thought that these factors are more critical in an urban setting.

### **Urban Line of Sight**

A new algorithm to determine line of sight (LOS) obstructions is being implemented in the BTO program. The algorithm, on the open battlefield, assumes that the battlefield is partitioned into rectangles and that elevation data is available at grid points and that bilinear interpolation is used to calculate elevations at non-grid points. Elevations at all terrain points, along with the elevations along the LOS can be represented as a quadratic polynomial and a linear polynomial, respectively, as functions of a common variable. The problem of determining an obstruction for a given LOS then reduces to solving a quadratic polynomial. One advantage of using bilinear interpolation over the OneSAF method of using triangles to represent terrain is that the resulting terrain trace along the projection of the LOS onto the XY plane is "smooth" and is probably more typical of open field terrain.

Modifications to the open terrain LOS algorithm are being made to extend this approach to the urban battlefield. With a model of the urban area, each structure is treated individually and the same approach is used as for open terrain. The first stage in this effort will be to treat the building as a solid object without windows, doors, or anything else that may allow a LOS to penetrate. The second stage will be to include those features excluded in the first stage. We suspect that bilinear interpolation on the urban battlefield may not be as useful as on open terrain because of the complexity of urban structures but we are investigating this question.

### **Urban Visualization**

Urban operations will also provide more challenges in how to depict the environment. In general, humans are more proficient at understanding data visually arranged than in simple literary format. With this in mind an effort has been made to meaningfully display ownership data that is informative and insightful, especially if/when real-time response is an issue. At the same time our goal is an efficient transmission and processing of this data by all computers attached to the semantic Web. This is the approach we took when implementing BTO for an open battlefield environment. The challenge now for us is an urban ownership technique that is likewise beneficial to our Soldiers.

The following explains current BTO information graphics and an initial method for visualization of urban ownership data. This includes two applications that have been developed and tested, and a method for frame-based rendering that is near completion; this latest capability with the

inclusion of time will provide a 4D BTO. All software is Web-friendly, designed using object-oriented principles, and implemented in Java with resulting data formatted in the extensible markup language (XML). This should allow for easy modification of existing software and minimize the level of effort necessary when integrating any new algorithms for urban operations. Currently BTO information graphics for a semantic Web consist of 2D and 3D techniques for visualization: a Scaleable Vector Graphics (SVG) application for displaying a 2D image of ownership at a particular instant (see Figure 2), and a Java3D program for affine transformation of digital terrain elevation data, both at level 1 and 2 (digital topographical elevation data - DTED-1 and DTED-2). Since SVG is XML supporting the document object model of a viewer, member data and methods are being written to allow for rapid update of the preceding frame.

Figure 3 illustrates a frame where a 2D transparent image ( $\alpha = 0.4$ , where  $\alpha$  value ranges from transparent to opaque on the unit interval) of ownership as determined for a particular OneSAF scenario is accurately registered with DTED-1 for the National Training Center in California. The color scheme samples the electromagnetic spectrum at selective points, and provides an alternative for display and interpretation without a legend on the graphic. Six classifications of ownership ratios are defined for the blue (B) and red (R) forces. The seventh and final classification designates “zero” owned areas and reflects that neither force has any influence due to weapon range restrictions.

Classifications	Color
B:R $\geq$ 6:1	Strong blue
3:1 $\leq$ B:R < 6:1	Medium blue
1:1 $\leq$ B:R < 3:1	Weak blue
R:B $\geq$ 6:1	Strong red
3:1 $\leq$ R:B < 6:1	Medium red
1:1 $\leq$ R:B < 3:1	Weak red
Zero owned	White

Figure 4: Classifications

Also note the darker areas in Figure 3 are the result of positioning the directional light source. The angle between this direction vector and the selected viewing position resulted in the desired 3D effect.

Military operations on urban terrain are difficult to simulate. Our research team will be using the next-generation OneSAF Objective System (OOS) for entity level simulation. And we believe that application of ownership methodology to an urban setting for OOS will additionally contribute to the success of our warfighters.

A major feature of any urban area is its buildings. OOS has a requirement that its environment data model define ultra-high resolution buildings (UHRB) using XML. Likewise our efforts will include determining and displaying ownership of a UHRB: initially, ownership of floor level(s), room(s), and hallway(s) if applicable. A UHRB description also includes other features such as fixtures and apertures that may have some influence on ownership determination. Implementation will be done using the extensible 3D (X3D) graphics language, which should

minimize the level of effort for modification and addition of new algorithms as needed for a Web-based environment. The Java-based X3D browser, Xj3D<sup>5</sup>, will be used for viewing scene content.

Note that the Modeling, Virtual Environments, and Simulation (MOVES) Institute at the Naval Postgraduate School provides a rather large archive of 3D military models from their Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) project<sup>6</sup>. Some UHRB prototypes<sup>7</sup> exist at this Web site and will be evaluated for our particular application.

## **Conclusions**

As we have noted, the technical challenges are many. Computational models that address the complexity of UO battle command have been problematic to develop. Army collaborative decision aids are generally inadequate to manage mixed assets (sensors, robots, and soldiers) and dynamic uncertainty. There are inadequate algorithms for dynamic information push/pull to support the integration of mixed assets into mission planning and urban combat, and inadequate environmental algorithms to support the situation analytical needs of the Commander/Soldier. Moreover, metrics to validate the effectiveness of enhanced battle command capabilities in UO seem elusive.

The approaches we have been taking are designed to address such challenges. We are striving to identify urban COA measures of effectiveness, mission abstractions, and wargaming parameters. Further, we are creating parameterization procedures to identify metrics meaningful during a particular battle phase. In particular, we are applying our techniques for data mining simulation results to analyses of lower echelon UO, incorporating dynamic killer/victim scoreboard and BTO graphics into decision aiding.

It is important to note that BTO can be used in different stages of the battle. With its current hookup to a combat simulation, BTO can assist in the mission planning phase. For example, a scenario can be configured in a combat simulation and executed numerous times to determine possible entity locations during and after the mission. The types and quantities of ammunition can be evaluated to augment the basic load of the entities. The fit of equipment on hand and the mission can be analyzed to determine if changing equipment or altering a mission would result in an improved battle outcome. By utilizing multiple iterations of a simulation BTO may help identify mission-critical features and assist in establishing objectives.

BTO currently executes based on simulation feeds; however, future work will incorporate real-world data from disparate sources. As BTO receives information from sensors and intelligence sources, it can serve as a monitor of battle execution. This will provide many advantages, including: a quick reference to each force's control of the battlespace; a color-coded battle map that delineates the active battle area and influences of each force in the battlespace; an evaluation of the advancement of the forces in the time allotted for tasks; and an understanding of "success" or the degree of mission completion.

BTO is the first component in a statistically-based automated tool set capable of producing battlespace analyses that describe occurrences key to the success of a military operation. BDST will sponsor a series of simulation-based experiments to quantify the worth of the technology. Metrics for

calculating warfighter payoff can include: increased plan development based on improved visualization of the operation during pre-mission wargaming; and during battle execution, reductions in friendly casualties and increased mission accomplishment enabled by monitoring the battlespace with the tool. The project by its nature is somewhat open-ended, but we hope that reasonable completeness, in the sense of transitionability, could be based on assessments by the Soldier proffered by the BCBL-L. The value added to the Army should be improvement in assessing battle areas of concern in a timely way, leading to a significant new type of decision aid.

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# Battlespace Terrain Ownership

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- ❑ Battlespace Terrain Ownership (BTO) computes control based on combat power projection as a function of position, asset distribution, weapon system effectiveness, probabilities of hit and kill, and damage
- ❑ A dynamic diagram updated as a battle progresses to aid the commander in timely prediction of crucial events
- ❑ The prototype is currently linked into streaming data from One Semi-Automated Forces (OneSAF) combat simulation to demonstrate ownership display





# Battlespace Data

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- ❑ **Modified OneSAF to produce data files containing both force interactions (combat) and entity status (logistics)**
- ❑ **Developed a Southwest Asia scenario depicting a company-sized assault on a numerically superior defense**
- ❑ **Prototype tested on open terrain conflict**





# Assumptions

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- ❑ Friendly (Blue) and Opposition (Red) force entity status and position are noted as they change
- ❑ For a given entity, any enemy entity may occupy a partitioned area being considered
- ❑ Each entity may fire whatever rounds are available
- ❑ Knowledge of opposition weapon systems and capabilities

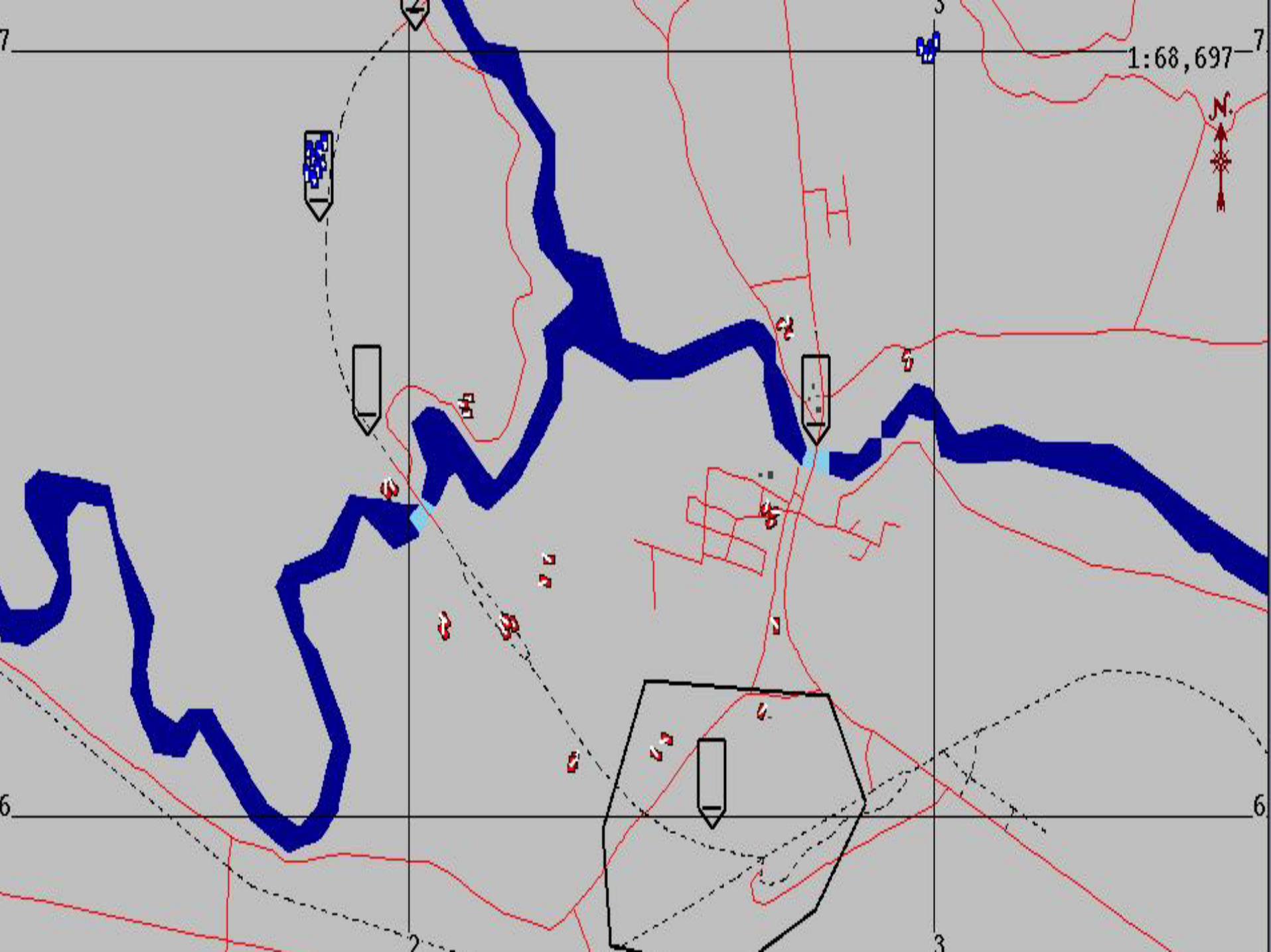


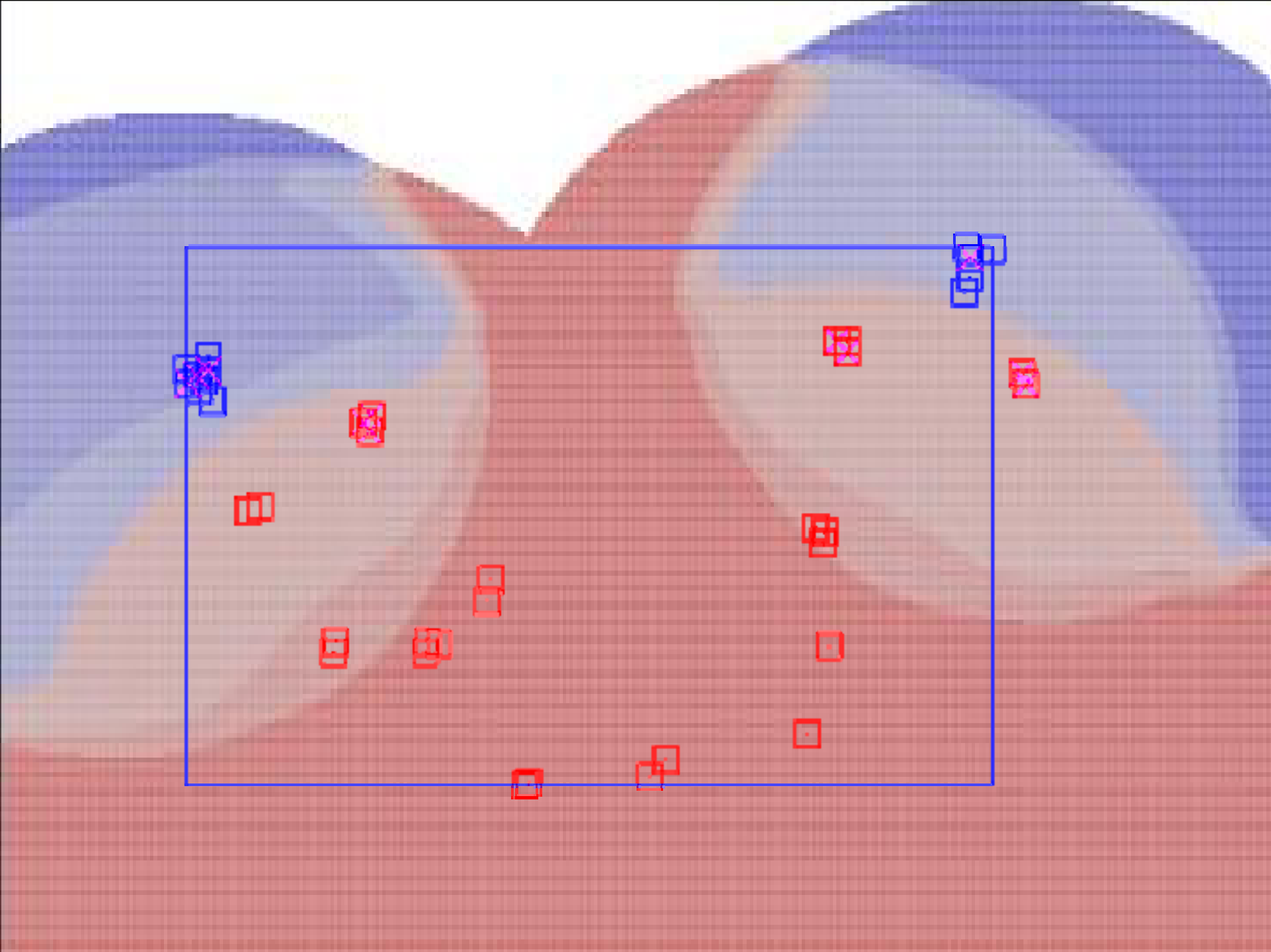
# BTO Algorithm

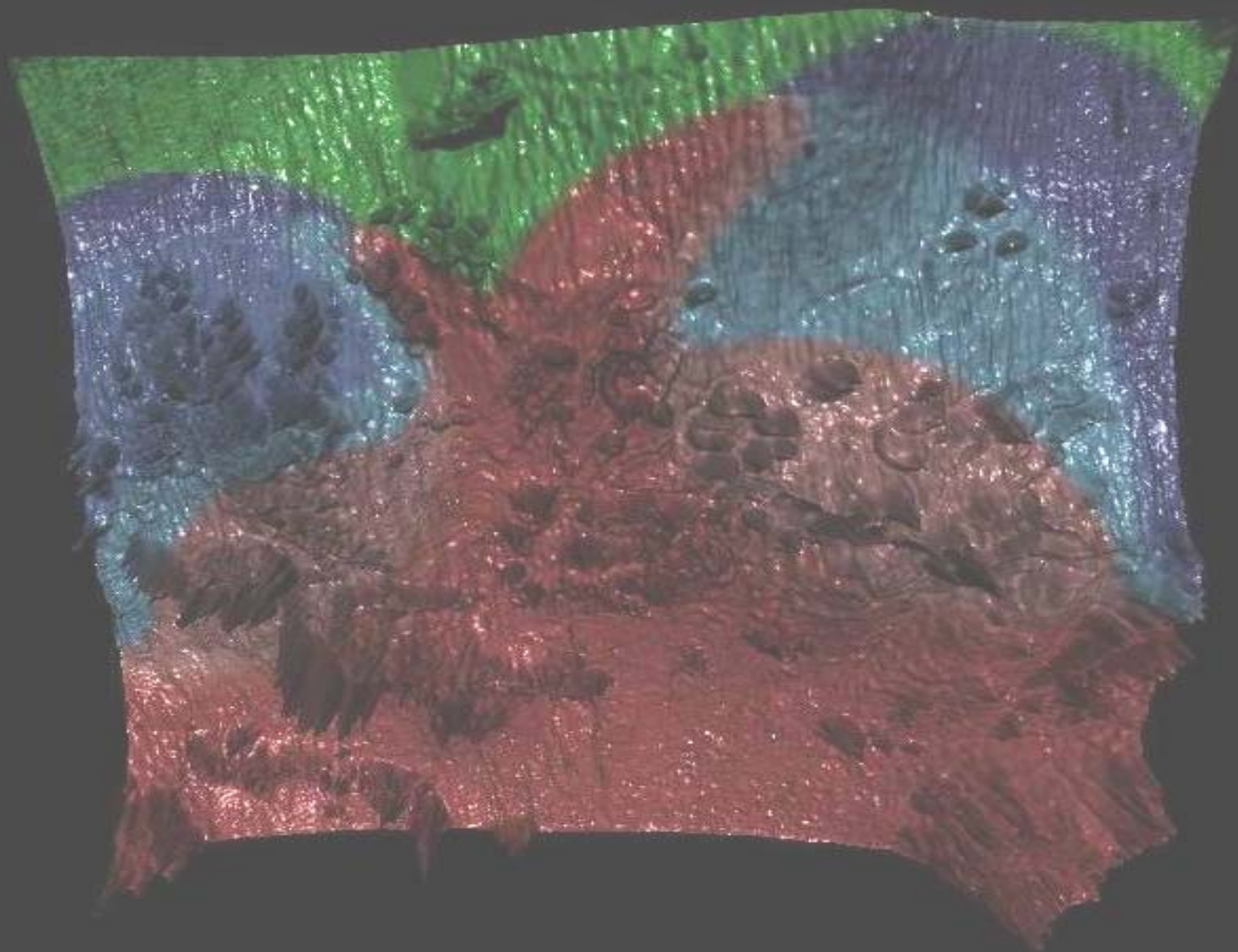
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- ❑ Partitions the battlefield into a number of rectangular areas for individual examination and determines the collective power that each force is able to project onto an individual area
- ❑ Seven classifications of power ratios:
  - $\geq 6:1$  (Blue and Red)
  - $\geq 3:1$  and  $< 6:1$  (Blue and Red)
  - $\geq 1:1$  and  $< 3:1$  (Blue and Red)
  - A zero owned class (due to weapon range restrictions)
- ❑ Areas for each class are color coded and plotted
- ❑ Also have probability of various kill types (M, F, MF, K) given a hit for each type round against each type vehicle, as a function of range, round dispersion, angle of attack, and hit location











# BTO Enhancements



## □ Completed

- Created JAVA GUI to launch OneSAF and BTO
- Ported BTO to Linux environment
- Improved OneSAF interface to reduce amount of human interaction necessary for data collection
- OneSAF modified to report indirect fire events
- Demonstrated BTO at Ft. Leavenworth for input on features and improvements

## □ In Progress

- Developing overlay so ownership graphic will display on map
- Creating ownership algorithm for urban environments



# Urban Conflict

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- ❑ Complex and multi-dimensional
- ❑ Societal characteristics
- ❑ Produces food and water shortages, pollution, and disease
- ❑ Criticality of urban infrastructure
- ❑ Military decision-making factors tend to be compressed
- ❑ Population has a greater effect

# Urban Classifications

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- ❑ Offensive
  - Surprise, boldness, and force concentration
- ❑ Defensive
  - Preparation, security and adaptability
- ❑ Stability and Support
  - Interactions between civilian populations and organizations



# Interviews

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- ▣ Nine SMEs at Battle Command Battlelab – Ft. Leavenworth
- ▣ Showed BTO open terrain demonstration
- ▣ Asked for input on improvements to BTO
- ▣ Asked for input on how to modify BTO for urban conflict

# Urban Recommendations – Interview Results

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- ❑ Criticality of personal involvement
- ❑ Socioeconomic data
- ❑ Presence may afford more control than firepower
- ❑ Importance of dismounted infantry
- ❑ Modeling of infrastructure elements, man-made obstructions, force degradation

# Urban Visualization

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- Use scalable Vector Graphics (SVG) for 2D display
- Generate a transparency of ownership with accurate registration for 3D display using Java3D Application Interface
- Provide rapid update of ownership data in SVG by scripting the document object model (DOM) for the Apache Software Foundation Batik Viewer

# Urban Line of Sight (LOS)

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- ❑ New LOS algorithm created for open terrain BTO
- ❑ Partitions battlespace into rectangular grid
- ❑ Elevations are represented as quadratic polynomials
- ❑ To determine obstructions, solve the quadratic polynomial
- ❑ Smoothing of open terrain
- ❑ May not improve urban LOS

# Urban Challenges

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- ❑ Inadequate algorithms for dynamic information push/pull
- ❑ Inadequate environmental algorithms to support analysis
- ❑ Metrics to evaluate if battle command capabilities are enhanced
- ❑ Decision aids are not good at handling mixed assets – sensors, robots, and soldiers

# The Road Ahead

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- ❑ Identify urban COA measures of effectiveness
- ❑ Mission abstractions
- ❑ Wargaming parameters
- ❑ Modify power projection algorithm to include urban factors
- ❑ Improved Urban LOS?
- ❑ Improved visualization
- ❑ **Other Suggestions?**

# Conclusion

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**BTO enables a real-time visualization of the battlespace, presented without excessive details, to help the commander recognize force potentials and terrain control in battle monitoring and execution. This capability must be extended to the urban environment.**



# Questions?

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